

## ZnNi data

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# Additional Corrosion Testing



**Table 1 - Machine vs. Carbide Scribed Corrosion Test**

Group No.	Test Specimen* Identification	Plating Material	Conversion Coat Type	Plating Thickness (mils)	Primer + Topcoat	Type of Scribe	Test Duration**	Test Results
1	BC1	Zn-Ni	TriCr	0.6 +/- 0.15	Yes	Machined Scribe	1000 hrs	PASS
	BC2	Zn-Ni	TriCr	0.7 +/- 0.1	Yes	Machined Scribe	1000 hrs	PASS
	BC3	Zn-Ni	TriCr	0.7 +/- 0.1	Yes	Machined Scribe	1000 hrs	PASS
2	HC1	Zn-Ni	TriCr	0.8 +/- 0.2	Yes	Machined Scribe	1000 hrs	PASS
	HC2	Zn-Ni	TriCr	0.8 +/- 0.1	Yes	Machined Scribe	1000 hrs	PASS
	HC3	Zn-Ni	TriCr	0.8 +/- 0.2	Yes	Machined Scribe	1000 hrs	PASS
3	HC4	Cd	HexCr	0.8 +/- 0.05	Yes	Machined Scribe	1000 hrs	PASS
	HC5	Cd	HexCr	0.7 +/- 0.1	Yes	Machined Scribe	1000 hrs	PASS
	HC6	Cd	HexCr	0.5 +/- 0.1	Yes	Machined Scribe	1000 hrs	PASS
4	BS1	Zn-Ni	TriCr	0.8 +/- 0.05	No	Machined Scribe	1000 hrs	PASS
	BS2	Zn-Ni	TriCr	0.7 +/- 0.05	No	Machined Scribe	1000 hrs	PASS
	BS3	Zn-Ni	TriCr	0.8 +/- 0.05	No	Machined Scribe	1000 hrs	PASS
5	HS1	Zn-Ni	TriCr	0.8 +/- 0.1	No	Machined Scribe	1000 hrs	PASS
	HS2	Zn-Ni	TriCr	0.8 +/- 0.05	No	Machined Scribe	1000 hrs	PASS
	HS3	Zn-Ni	TriCr	0.8 +/- 0.1	No	Machined Scribe	1000 hrs	PASS
6	HS4	Cd	HexCr	0.8 +/- 0.1	No	Machined Scribe	1000 hrs	FAIL
	HS5	Cd	HexCr	0.7 +/- 0.1	No	Machined Scribe	1000 hrs	FAIL
	HS6	Cd	HexCr	0.8 +/- 0.1	No	Machined Scribe	1000 hrs	FAIL
7	BS4	Zn-Ni	None	0.8 +/- 0.1	No	Machined Scribe	1000 hrs	FAIL ****
	BN1	Zn-Ni	None	0.7 +/- 0.1	No	No Scribe	1000 hrs	PASS ****

\*\*\*\* Group 7 test coupons were run without conversion coating and were not required to pass (i.e. information only)

**BR&T ASTM B 117 Corrosion Test Results**



# Additional LHE Zn-Ni Hydrogen Re-Embrittlement Testing



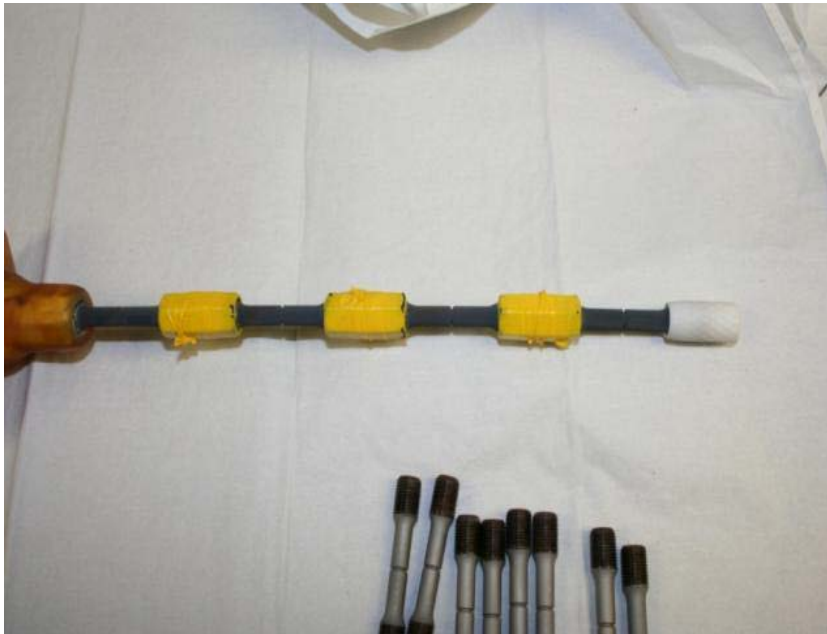
- The original LHE Zn-Ni test coupons failed due to poor plating in notch
- The reason for the poor plating on the original LHE Zn-Ni 1a.1 re-embrittlement coupons are as follows:
  - LHE Zn-Ni tank contamination
    - Spring '09 Lab analysis showed organic contamination
    - The PVC tank liner had begun to break down and had to be replaced in the Summer '09 with a more robust grade of PVC liner
    - Two years operating with new liner with no problems
  - Inconsistent plating in notch area
    - Specimens were chained in series when they were plated for the first series of tests
    - Now a fixture and conformal anode is used to ensure that there is uniform plating throughout the notch area per production process specification
    - Also circulation has been added around the notch area during plating



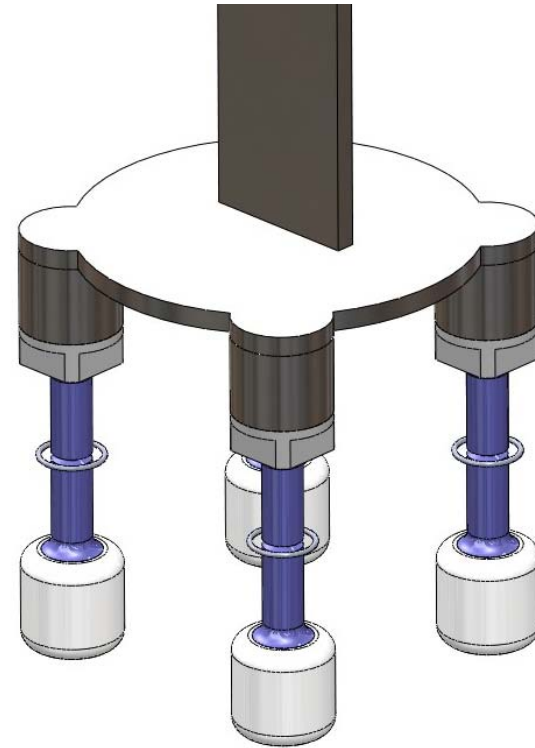
# Additional LHE Zn-Ni Hydrogen Re-Embrittlement Testing



**Original Coupons Chained in Series**

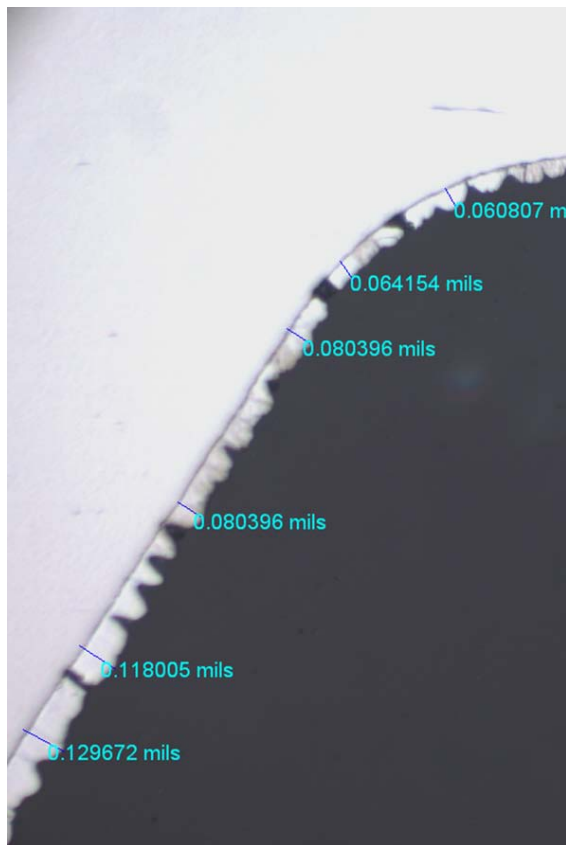


**New fixture and Conformal Anode**

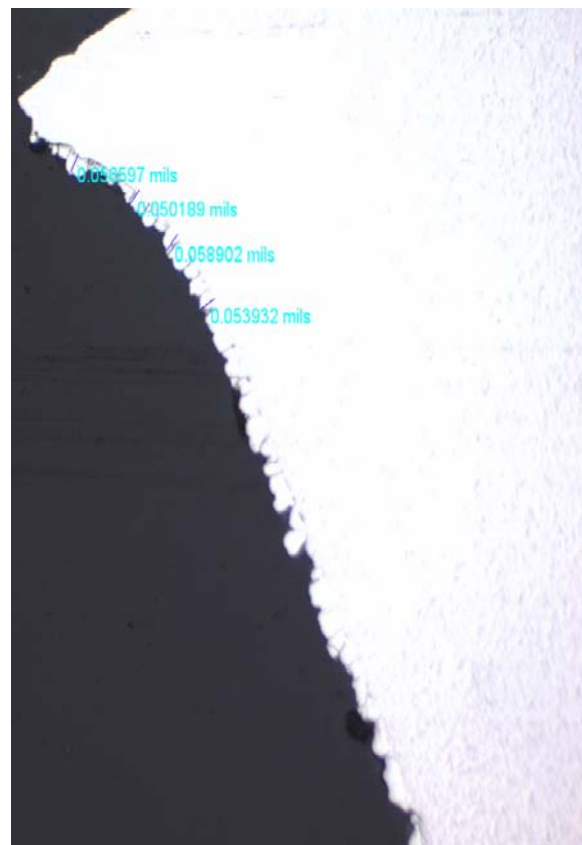




# Additional LHE Zn-Ni Hydrogen Re-Embrittlement Testing



Current plating with fixture  
and conformal anode



Contaminated plating  
chained in series



# Additional LHE Zn-Ni Hydrogen Re-Embrittlement Testing



- Additional, 3.5% salt water, re-embrittlement testing was conducted on LHE Zn-Ni plated coupons and they all passed the ASTM 519-06 150 hour requirement
- Cadmium and IVD Aluminum coupons were not re-tested because they are already approve for use on high strength steel

Re Embrittlement Test Matrix						
Plating	Test Solution					
	Distilled Water @ Room Temp Tested 45% NFS for 150Hrs	3.5% Salt Water @ Room Temp Tested 45% NFS for 150Hrs	Dwg 9825019* Diluted Calla 296 @ Max Temp 180 °F Tested 75% NFS for 200Hrs	Dwg 9825019* Diluted Calla 602 LF Max Temp 160 °F Tested 75% NFS for 200Hrs	Concentrated Calla 296 @ Room Temp tested 45% NFS for 150Hrs	Concentrated Calla 602LF @ Room Temp tested 45% NFS for 150Hrs
LHE Zn-Ni	Passed	Passed	Passed	Passed	Passed	Passed
Cadmium	Passed	Failed	Passed	Passed	Passed	Passed
IVD	Failed	Failed	Not Tested	Not Tested	Not Tested	Not Tested

\*The specimens were immersed in the cleaning compound at the manufacturer's maximum recommended temperature, and appropriate cleaning concentration, for 30 minutes. Removed. Air dried and loaded to 75% NFS for 200Hrs.



# Hydrogen embrittlement

- In addition Boeing, Heroux have also carried out HE testing and passed, so that issue is resolved
- Concern over dezincification

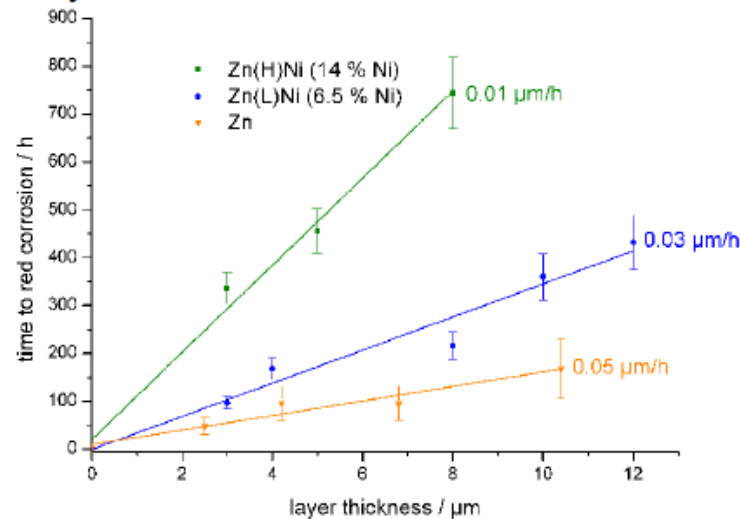


## Zinc-nickel alloy coatings

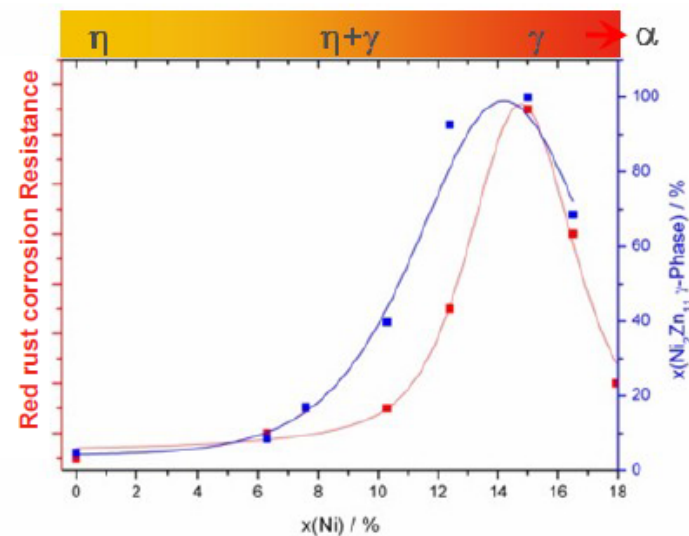


Corrosion protection and alloy composition / NO post-treatment

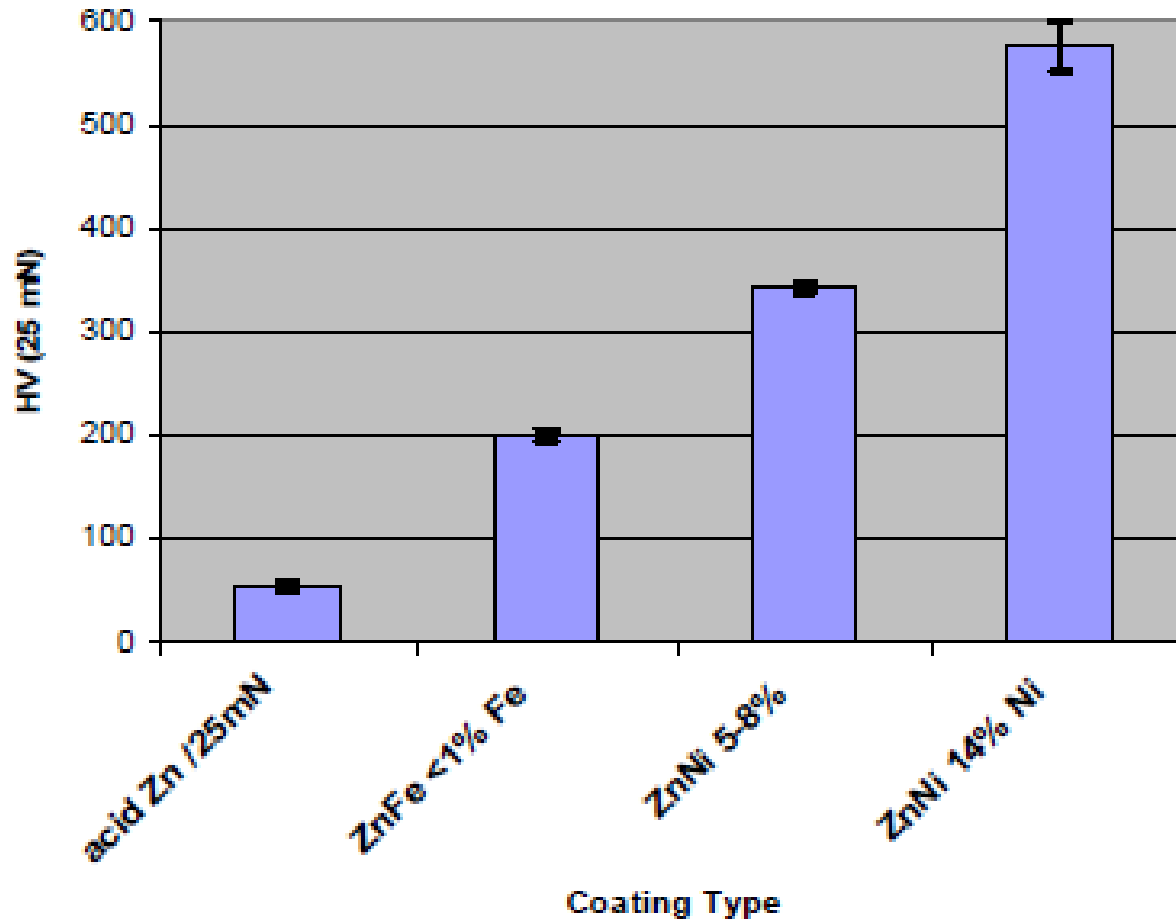
Zn/Ni in ISO 9227 NSS / time until red corrosion alloy



Ni<sub>2</sub>Zn<sub>11</sub> γ-phase conc. vs Ni fraction in



**Best cathodic corrosion protection with γ-zinc-nickel alloy!**



Not sure others have measured same hardness, but ZnNi is a lot harder than Cd



# De-Zincification Testing

- Questions have been raised about the potential impact of dezincification of the Zn-Ni plating
- 417 SCMS/GUEA, BR&T and ES3 are currently reviewing past industry de-zincification studies
  - Initial findings show that the corrosion electro-potential is consistent throughout the corrosion process
- 417 SCMS/GUEA, BR&T and ES3 will identify any additional testing that might be required to address dezincification

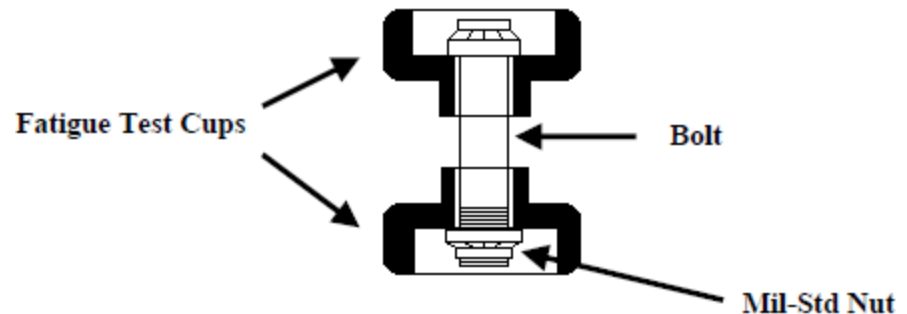
I suspect it does not lose Zn because it is a true single phase alloy

# Fatigue Test Results (Alkaline Zinc-Nickel, Phase IV)

Engineering, Operations & Technology | Boeing Research & Technology

Chemical Technology

- Nickel Alloy 718 Bolts – 3/8” diameter  
Cd or Zn-Ni plated
- Test Nuts – MIL-STD-1312 uncoated
- Test setup – Per NASM1312-11
- Test parameters
  - Cycle = 24 Hz, RT
  - Tension-tension at 1090 lbs (low) and 10900 lbs (high)
- Requirement
  - Acceptance = 100000 cycles or meets statistical requirement
- Results – Alkaline Zn-Ni plating on fasteners performed comparable to Cd



Part No.	Fastener Combination	
Bolt	BACB30US(Cadmium)	BACB30US(Zn-Ni)
Nut	MIL-STD-1312	MIL-STD-1312
Test No.	Cycles	Cycles
1	130000	119410
2	130000	130000
3	130000	130000
4	130000	130000
5	130000	130000
6	130000	108618
Average	130000	124671

Louie Tran, Boeing  
ASETSDefense 2009

- Passes all testing as equal to or better than Cd
- Being adopted throughout world for aircraft structures and fasteners
- Not necessarily best for connectors
  - ❑ Non-Cr passivates have too high impedance
  - ❑ SERDP work on alternative passivate ongoing



## Database



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